VIII. *The* Croonian *Lecture on Muscular Motion.* *By* Everard Home, *Esq. F. R. S.*

Read November 11, 1790.

WHEN I recollect the many learned men who have given this lecture, I cannot but feel myself much flattered by the honour of being named to that office ; I feel, at the same time, my own inability to explain many of the phænomena of muscular motion ; yet more its principle, the subject to which this lecture was originally confined.

The many, and perhaps insuperable, difficulties which obstruct our progress towards that knowledge, have led the ablest anatomists and physiologists, who have been called upon by this learned Society for their observations upon muscular motion, to deviate from the original intention of the founder, and instead of attempting an investigation of the principle, to explain the anatomical structure, and various phænomena of muscles with which they were acquainted ; that by this means they might furnish data for future inquiries.

I shall consider the example of such men as sufficient authority for not confining myself too closely to the subject prescribed ; and content myself with giving such facts and observations respecting muscles, as have not, I believe, been already laid before this learned Society.

This lecture was given for several years by Mr. HUNTER,

who still continues to prosecute the subject; and should the
following observations contain any new materials, it is from
that source that many of them are derived: for in my pecu-
liar situation, I should little merit the honourable task assigned
to me, were I not to avail myself of every advantage in my
power, that could make the present lecture worthy the atten-
tion of this learned audience.

The principle of action in an animal, appears to be as exten-
sive as life itself, and is almost the only criterion by which we
can distinguish living matter from dead.

This action does not seem to depend so much upon struc-
ture, as upon a property connected with life, which is equally
extensive in its principle, and so far as we are yet acquainted,
equally concealed from the researches of human sagacity.

To acquire a sufficiently enlarged notion of this principle,
we must not confine our inquiries to one set of animals, but
must take into our view the whole chain of animated beings;
and from a review of the different circumstances in which it
occurs, and the varied structure of parts upon which it is im-
pressed, we shall have sufficient evidence that the fasciculated
fibrous structure commonly met with is not necessary to its ex-
istence, but only made use of for its support, and continuance.

The structure which produces muscular action, varies so
much in different animals, that we are at a loss to conceive
how the effects should have the least similarity; and it is in
some cases, only from witnessing the actions that we can con-
sider the parts as muscles; since in nothing else do they bear
a resemblance to the muscular structure in the more perfect
animals with which we are best acquainted.

We shall illustrate this observation by a description of the

structure, and actions, of the animals called hydatids, which appear from their simplicity to be the furthest removed from the human ; for as the human is the most complicated, and most perfect in the creation, the hydatid is one of the most simple, and composed of the fewest parts. It is to appearance a membranous bag, the coats of which are so thin as to be semitransparent, and to have no visible muscular structure. From the effects produced by the different parts of this bag while the animal is alive, being exactly similar to the contractions and relaxations of the muscular fibres in the human body, we must conclude that this membrane is possessed of a similar power ; and consequently, has the same right to be called muscular.

The hydatid, from its apparent want of muscles, and other parts which generally constitute an animal, was for a long while denied its place in the animal world, and considered as the production of disease ; we are, however, at present in possession of a sufficient number of facts, to ascertain, not only that it is an animal, but that it belongs to a genus of which there are several different species.

Hydatids are found to exist in the bodies of many quadrupeds, and often in the human ; the particular parts most favourable to their support appear to be the liver, kidneys, and brain, although they are sometimes detected in other situations.

One species is globular in its form, the outer surface of the bag smooth, uniform, and without any external opening ; they are seldom found single, and are contained in a cyst, or thick membranous covering, in which they appear to lie quite loose ; having no visible attachment to any part of it. This species is most frequently found in the liver and kidneys, both of the

quadruped and human subject. They vary in size, but those most commonly met with, are from one quarter of an inch to three quarters of an inch in diameter.

Another species is of an oval form, with a long process, or neck, continued from the smallest end of the oval, at the termination of which, by the assistance of magnifying glasses, is to be seen a kind of mouth; but whether this is intended merely for the purpose of attachment, or to receive nourishment, is not easily determined. This species is found very commonly in the brain of sheep, and brings on a disease called by farmers the staggers. It is not peculiar to any one part of the brain, but is found in very different situations, sometimes in the anterior, at others in the posterior lobe. It is inclosed in a membranous cyst like the globular kind; but differs from that species in one only being contained in the same cyst; and the bag, or body of the animal, being less turgid, appearing to be about half filled with a fluid, in which is a small quantity of white sediment; while the globular ones are in general quite full and turgid.*

This species, from its containing only a small quantity of fluid, has a more extensive power of action on the bag, and is therefore best fitted for illustrating the muscular power of these animals.

If the hydatid be carefully removed from the brain, immediately after the sheep is killed, and put into warm water, it will soon begin to act with the different parts of the body, exhibiting alternate contractions, and relaxations. These it performs to a considerable extent, producing a brisk undulation

* The species of hydatid without a neck is also met with in the brains of sheep, but is less turgid, and less of a spherical figure, than those commonly found in the liver.

of the fluid contained in it; the action is often continued for above half an hour, before the animal dies; and is exactly similar to the action of muscles in the more perfect animals. This species of hydatid, is very well known by the name *tænia hydatigenia*; it varies considerably in its size; one of those which I examined alive, was above five inches long, and nearly three inches broad at the broadest part, which makes it nine inches in the circumference.

The coats of the hydatid, in their recent state, exhibit no appearance of fibres, even when viewed in the microscope; but when dried, and examined by glasses of a high magnifying power, they resemble paper made upon a wire frame. This very minute structure is not met with in membranes in general; it may therefore be considered as the organization upon which their extensive motions depend.

The coats of the different species of hydatids had all of them the same appearance in the microscope.

The intestines, in some of the more delicately constructed animals, have a membranous appearance, similar to the bag of the hydatid, and we cannot doubt of their possessing a muscular power, since there is no other mode of accounting for the food being carried along the canal. The action of the intestines, not coming so immediately under our observation, makes them a less obvious illustration of this principle than the hydatid; we may, however, consider their having a similar structure, as a strong confirmation of it.

If we compare the structure of muscles in the human body, with that of the membranous bag, which composes the *tænia hydatigenia*, a structure evidently endowed with a similar principle of action, the theories of muscular motion, which are

founded upon the anatomical structure of a complex muscle, must be overturned.

The simplicity of form, in the muscular structure of this species of hydatid, makes it evident, that the complex organization of other muscles, is not essential to their contraction and relaxation, but superadded for other purposes; which naturally leads us to suppose, that this power of action, in living animal matter, is more simple, and more extensively diffused through the different parts of the body, than has been in general imagined.

From these observations we shall find, that the inquiries hitherto made, into the principle of muscular motion, by investigating the muscles of the more perfect animals, which are most remarkable in their effects, and obviously most deserving of attention, have been too confined.

From our inquiry into the structure of muscles, in different animals, we readily discover, that those above mentioned, although the most perfect in their organization, are at the same time so complicated, for the purpose of adapting them to a variety of secondary uses, that they become of all others, the kind of muscle least fitted for the investigation of the principle itself.

In the present imperfect state of our knowledge respecting animal life and motion, a physiologist, who would select a complex muscle, with the view of discovering, from an examination of its structure, the cause of muscular contraction, would resemble a man, ignorant of mechanics, who should consider a watch as the machine best constructed to assist his inquiries respecting the elastic principle of a spring; which, at first sight, must appear absurd. For although the spring is the power

by which the motions are all produced, the machine is so complicated with other important or necessary parts, that the spring itself is not within the reach of accurate observation.

To prosecute an inquiry into the cause of muscular motion, with the greatest probability of success, recourse should be had to muscles, which are in themselves the most simple ; and we should endeavour to ascertain what organization, or mechanism, is essential to this action in living animal matter, by which means we should acquire a previous step to the investigation of the principle itself.

The complex muscles in the more perfect animals, from their structure and application, open a wide field of inquiry; for we shall find that it is from their different organizations, that they are enabled to perform the various actions of the body; actions too powerful and extensive for muscles to effect, unaided by such complication of structure, and the advantages derived from it.

In the present lecture, I shall confine myself to the consideration of the most important uses of the complex structure of muscles, and by this means make it evident, that they are not indebted to it for the principle upon which muscular motion depends.

These complications are necessary to supply the muscle with nourishment, for the continuance of its action ; to give it strength ; to enable it to vary its contraction from the standard or ordinary quantity ; and to increase the effect beyond the absolute contraction of the muscle. How these different purposes are effected, I shall endeavour to explain.

A muscle receives its nourishment from the blood, with which we find it more abundantly supplied than most other

parts of the body. This supply is evidently intended for the support of its action, since it is proportioned to the exertions of the muscle; and whenever a muscle is rendered incapable of acting, which frequently happens from the joints becoming stiff, the quantity of blood sent to it is very much diminished. The great vascularity of a muscle is, therefore, for the purpose of repairing the waste in the muscular fibres, occasioned by their action; and without this support, the continuance of their contractions would be of short duration.

The strength of a muscle must depend upon the number of its fibres, and most probably upon their size; since in strong muscles the fibrous appearance is very obvious, while in very weak ones no such structure is visible to the eye. A distinction of fibres has been considered as essential to the contraction of a muscle, and only those parts have been allowed to possess that power, in which fasciculi of fibres could be ascertained. But from the observations which have been made, it would perhaps be nearer the truth, to consider the circumstance of the fibres being distinct, as a proof of strength in a muscle, but not essential to the existence of muscular contraction.

There is a power inherent in a complex muscle, by which it can increase or diminish the ordinary extent of its contraction; this is very curious, and must arise from some change going on in the muscle itself, for which it is adapted by means of this very complicated organization.

The usual quantity of contraction which takes place in the fibres of a complex muscle, in the different motions of the human body, is adapted in the nicest manner to the circumstances in which the muscle is placed; and the quantity of contraction appears to be limited by the fibres having no power

of becoming shorter. We find, however, from observation, that when the extent of motion in a joint, or the distance between the fixed points of the muscle, is accidentally altered, the muscle acquires a power of adapting its quantity of contraction to the new circumstances which have taken place.

This power in a muscle may be considered as a proof that the principle of contraction is independent of its particular organization; since it can undergo a complete change within itself, so that its fibres shall be shortened to one half of their original length, and still have the same contractile power as when in its original state.

The extent of this principle is well illustrated by the following case. A negro about thirty years of age, having had his arm broken above the elbow joint, the two portions of the os humeri were unfortunately not reduced into their places, but remained in the state they were left by the accident, till the callus or bony union had taken place; so that when the man recovered, the injured bone, from the position of the fractured parts, was reduced almost one half of its length. By this circumstance, the biceps flexor cubiti muscle, which bends the fore-arm, remained so much longer than the distance between its origin and insertion, that in the most contracted state it could scarcely bring itself into a straight line: this muscle, however, in time, as the arm recovered strength, adapted itself to the change of circumstances, by becoming as much shorter as the bone was diminished in length; and by acquiring a new contraction in this shortened state, it was enabled to bend the fore-arm.

Some years after this accident, the person died, and the circumstances abovementioned being known, the parts were exa-

mined with particular attention. The biceps muscles of both arms were carefully dissected out, and being measured, the one was found to be eleven inches long, the other only five; so that the muscle of the fractured arm had lost six inches, which is more than the half of its original length. These muscles are now deposited in Mr. HUNTER's collection of preparations illustrating the animal œconomy.

That muscles possessed this power, has been taken notice of by Mr. HUNTER in a former lecture; but the instance which I have given, is so striking an illustration of this principle, that I could not avoid mentioning it while upon this subject.

Muscular contraction is an operation, in whatever way performed, by which the vital stores of the animal are considerably exhausted; this is evident from the quantity of blood with which muscles whose action is frequent are supplied.

This expence would appear, from observation, to be occasioned rather by the extent of contraction, than by its frequency, or force; for if we examine the mechanism of an animal body, we shall find a variety of structures evidently intended for no other purpose than diminishing, as much as possible, the necessary extent of contraction in muscular fibres, while there is no such prevention of frequency of action.

Muscles in general are applied to the bones in such way as to act with great mechanical disadvantages as to power; but this is more than compensated by the small quantity of contraction which is required; and in the muscles of respiration, we find frequency of action is preferred to an increased quantity of muscular contraction.

The velocity of motion thus acquired, although a considerable advantage, does not seem to have been the principal

object intended by such structure, but rather to procure the effect by means of short contractions, which are less fatiguing, or in some other way more in the management of the constitution, than long ones.

That long contractions in a muscle cannot be supported for any length of time, may be illustrated from the actions both of the voluntary and involuntary muscles.

While the voluntary muscles are under the command of the will, we cannot ascertain what would be the effects produced by the continuance of their contractions, since the influence of the brain communicated by the nerves becomes soon weakened, and puts a stop to their action; but when the contractions of voluntary muscles are by any circumstance rendered involuntary, the difference in the time of their continuance appears to be in the inverse proportion of the quantity of contraction; for muscles, whose usual functions consist in short contractions, can go on for a long time, while those which are performed by long contractions soon cease.

In the muscles of a paralytic arm, their action, to a certain extent, is continued for years (the times of sleeping excepted), without any effect being produced upon the constitution, or the parts themselves; but in epileptic fits, in which the actions are equally involuntary, only requiring longer contractions, they soon cease, leaving the person greatly exhausted; an effect which must arise from the quantity, not the frequency, of the contractions.

If we attend to the actions of the involuntary muscles, we find that they are continued through life, but that the quantity of contraction is very small; and if from any circumstance the quantity should be increased, it cannot be continued, the

parts being unable to sustain it for any length of time. The diaphragm, and intercostal muscles, act constantly in performing the functions of respiration, but they do not exert themselves to their full extent. In laughing, which is likewise an involuntary action, the contractions of these muscles are more extensive, therefore if continued beyond a very short period become so distressing, that a cessation necessarily ensues.

Muscular contraction is never made use of in an animal body, where any other means can produce the same effect, and for this reason elastic ligaments are frequently substituted for muscles; even where muscles are employed, various means are applied to diminish the quantity of contraction.

It is curious, in tracing the different forms of muscles, and in considering the uses for which they are employed, to observe how variously the fibres are disposed, evidently for the purpose of obviating the necessity of great contractions; and the quantity of muscular action saved by this mechanism is greater, in proportion to the frequency and importance of the effect the muscle is intended to produce : this appears to be invariably the case.

Muscles only occasionally called into action, have their fibres nearly straight, which gives no mechanical advantage; the sartorius is an instance of this kind.

Muscles frequently used are more complicated, as those of the fingers are half penniform in their structure; the muscle for raising the heel in walking is penniform; that which raises the shoulder, complex penniform; and those of the ribs, cruciform.

That the two sets of intercostal muscles act at the same time, I proved by experiment in the year 1776. I removed

a portion of the external intercostal muscles from the chest of
a dog, and in that way saw very distinctly the two sets of
muscles in action. The fibres of both sets contracted exactly
at the same time.

The particular structures of these different forms of muscles,
and the mechanical advantages arising out of them, have been
already explained in former lectures upon this subject; but
there is a form of muscle, in which the disposition of fibres pro-
duces a considerable saving of muscular contraction, that has
not been at all taken notice of.

The muscle I allude to is the heart, the most important
in the body, whether we consider the frequency of action,
or the office in which that action is employed; and we shall
find, upon examination, that the fibres are disposed differently
from those of any other muscle, which disposition of fibres ap-
pears to have a superiority, in being enabled to produce their
effect by a smaller quantity of contraction.

In considering the muscular structure of the heart, it is only
intended to examine that part of it called the ventricles, which
may be reckoned two separate muscles. The right ventricle,
for sending the blood through the vessels of the lungs, called
the lesser circulation; the left, to propel it through the
branches of the aorta, which go to every part of the body,
called the greater circulation.

If these two ventricles are superficially examined, the mus-
cular partition by which they are united seems to belong equally
to both, one half of it appearing to be a portion of the right,
the other of the left ventricle.

In this view, the sides of the left ventricle, although evi-
dently more muscular and thicker than those of the right, are

by no means stronger in proportion to the difference of effects they have to produce. We find, however, upon dissection, that the septum is almost wholly a portion of the left ventricle, which gives it a great superiority over the other, and makes it capable of performing the important office of supplying the body with blood.

The left ventricle of the heart, detached from the other parts, is an oviform hollow muscle, but more pointed at its apex than the small end of a common egg. It is made up of two distinct sets of fibres, laid upon one another in the form of strata; those which compose the outer set have their origin round the root of the aorta, and in a spiral manner surrounding the ventricle to its apex, or point, where they terminate, after having made a close half turn. The fibres of the inner set, or stratum, are similar to those of the outer, in their origin, in the mode of surrounding the cavity, and in their termination, but their direction is exactly the reverse; they decussate the outer set in their whole course, and where the two sets terminate, they are both blended into one mass. There is an advantage gained by this disposition of fibres over every other in the body, which adapts the ventricle so perfectly to its office, that it would almost appear impossible to construct it in any other way, so as to answer the purposes for which it is intended.

In this muscle, the fibres, by their spiral direction, are nearly one fourth part longer than the distance between the origin and insertion; and the action of the two sets being in different directions, renders only one half the quantity of contraction in each fibre necessary, that would have been otherwise required; while the turn both sets make in opposite directions

at the apex of the ventricle, fixes it and prevents lateral motion.

In the action of the ventricle, two different effects are pro-duced ; the first brings the apex nearer to the basis, by which means the *vis inertiæ* of the blood will be overcome where the resistance is least, and a direction given to its motion in the course of the aorta ; the second brings the sides nearer each other, which will accelerate the motion of the blood already begun ; and the spiral direction of the fibres, will render the power which is applied, more uniform through the whole of that action, than it could have been made by any other known form of muscle ; the spiral action will also readily shut the valvulæ mitrales, while the apex is drawn up, which could only be effected by this particular construction.

By this beautiful mechanism, which I have endeavoured to describe, the muscular fibres of the left ventricle of the heart perform their office with a smaller quantity of contraction, compared to their length (although in themselves proportion-ally longer), than those of any other muscle in the body, and consequently produce a greater effect in a shorter time.

The right ventricle is situated upon the outside of the left, with which it is firmly united ; it is not oviform in its shape, but triangular ; nor is it uniform in its structure, being made up of two portions, whose fibres have a very different distri-bution.

The portion of this ventricle which makes a part of the septum of the heart, consists of only one set of fibres, similar in their direction to those of the stratum underneath, belong-ing to the left ventricle ; but from being considerably shorter, they are more oblique than the spiral ; and at the edge of the

cavity they are blended with the fibres of the opposite portion.

That portion which is opposite to the septum is composed of three sets of fibres; those of the external set are nearly longitudinal; the two others, which lie under it, decussate each other, and are obliquely transverse in their direction, one passing a little upwards, the other downwards; and both terminate upon the edge of the septum.

In the structure of this muscle we find none of the mechanical advantages, so obvious in the left ventricle; the want of these, however, is in some measure compensated by its situation; for the blood contained in its cavity, will have the *vis inertiæ* overcome, and a direction given to its course by the action of the apex of the left ventricle : that motion only requiring to be continued, and accelerated, for which purpose the structure of this muscle is very well calculated; and in which it will also be assisted by the lateral swell of the septum into its cavity, in the contraction of the left ventricle.

In the course of this lecture, it has been my endeavour to show the most simple structure that is capable of muscular action; and to point out the advantages intended to be produced by the different complications which occur in an animal body.

The view which I have taken of this subject gives us an idea of the extent to which muscular action is employed in different animals; and leads to the belief, that very dissimilar structures in the more perfect animals are endowed with this principle, since the actions of the smaller arteries, as well as of the absorbent vessels, must be referred to it.

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To ascertain whether any such action could be demonstrated in the membranes of the quadruped, I made the following experiments.

These experiments were made upon the internal membrane of the urinary bladder of a dog, which, in consequence of the animal dying a violent death, was in a very contracted state; the whole of its contents having been expelled in the act of dying.

The method I have adopted to ascertain the muscular power of this membrane, is similar to that taken by Mr. HUNTER in his very ingenious investigation of the structure of blood-vessels, which was laid before this Society; the same mode being equally applicable to the present subject.*

The bladder was carefully laid open, and a portion of its internal membrane, which was corrugated into folds, was dissected off. This portion was spread out, so as to be completely unfolded; it was then laid upon a piece of plate glass wetted, to prevent, as much as possible, any friction; its exact length, in this contracted state, was three quarters of an inch; it was now stretched out, and found to be $1\frac{3}{8}$ inch, upon being left to itself, it contracted so as to be only 1 inch, so that in this state it had gained $\frac{2}{8}$ of an inch, which must have been lost by some action in the living body, and entirely independent of its elasticity. This portion of membrane then had two powers of contraction, one which was muscular, and equal to $\frac{2}{8}$ of an inch, the other elastic, and equal to $\frac{3}{8}$ of an inch.

Another portion of the same membrane, $\frac{1}{2}$ an inch long and

* Mr. HUNTER's experiments on the arteries of the horse are published in his treatise on the Blood, Inflammation, and Gun-shot Wounds.

$\frac{5}{8}$ broad, was treated in the same way, and its muscular contraction was found to be $\frac{1}{8}$ of an inch, that from elasticity $\frac{4}{8}$ of an inch.

A third portion of membrane $\frac{7}{8}$ of an inch long, and $\frac{2}{8}$ broad, was ascertained to have contracted $\frac{2}{8}$ of an inch by its muscular power, and $\frac{3}{8}$ from its elasticity.

It will scarcely be necessary to mention, that the muscular contraction in this membranous structure, is very readily overcome, since this must be almost self-evident; that circumstance, however, must be particularly attended to in making similar experiments.

The internal membrane of the urethra we know to be capable of contracting, as spasmodic strictures are formed in that canal. This membrane, when dried and examined in the microscope, has not the same appearance as the coats of the hydatid; but the whole is a congeries of vessels forming a network. We must, therefore, suppose that the action is in these very minute vessels.

From these experiments and observations, membranous structures are found to exert an action hitherto denied them; and it is equally evident, that this principle is applied to the purposes of the animal œconomy in a more extensive manner than has been generally imagined.

To explain even the most obvious phænomena of muscular motion, must appear from the above observations to be attended with difficulty; how arduous then the task of investigating the principle upon which that motion depends; a principle as extensive as life itself, with which it is coeval, and indeed the only criterion we have of its existence.

An endeavour to throw light upon that principle, has not been the object of the present lecture; I have only attempted to state some circumstances respecting the mechanism employed in producing muscular motion, leaving to others the prosecution of this most intricate and difficult inquiry.

ERRATA.

Page 42, line last, *for* C, *read c.*

Page 115, line last but one, *instead of* B. ad H. *perhaps it should have been* B. ad C.